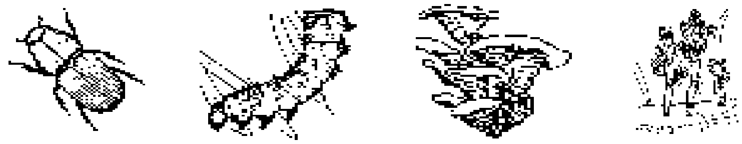
rest He
Protection



Report 02-7 **April 2002**

AN ASSESSMENT OF CHLORIDE-ASSOCIATED, AND OTHER ROADSIDE TREE DAMAGE, ON THE SELWAY ROAD, NEZ PERCE NATIONAL FOREST

Susan K. Hagle, PhD
Plant Pathologist

ABSTRACT

Tree damage following dust abatement/road stabilization treatment was evaluated on 12.5 miles of the Selway River Road, Nez Perce National Forest. Calcium chloride was applied in June of 2000, mostly at a rate of 5lb/yd^2 (18,600 lb./acre) or 6.9 lb/yd^2 (25,700 lb/acre). 1,189 trees up to 30 feet from the road were examined in June 2001 and again in December 2001. Western redcedar and Douglas-fir were most damaged by the chloride. Ponderosa pine was the most tolerant of the tree species. Severity of damage was associated with tree species, proximity of trees to road, and $CaCl_2$ application rates. Cedar foliage samples collected in November 2001 from symptomatic trees near treated road averaged nearly seven times more chloride ion concentration than the controls. Treated Douglas-fir averaged 50 times more and ponderosa pine average 30 times more than their respective controls. As of December 2001, 12% of cedars were dead and another 18% appear to be dying. Douglas-fir fared worse with 29% dead and 12% dying. Grand fir and ponderosa pine had only 6% and 4%, respectively, dead or dying.

INTRODUCTION

The Selway River Road is a single-lane road adjacent to the lower Selway River. It primarily provides recreation access to the river and to wilderness trails in summer and fall. Potholes, dust, washboards and boulders in the road surface have limited serviceability of the road. Sediment has been a concern as well. In June of 2000, solid (flake) calcium chloride was applied to a section of the Selway River Road as part of surface treatments to stabilize the road (Monlux and Calcaterra 2001). Treatment also included in-place processing of the native road surface to a 6-inch depth and addition of crushed basalt. In the spring of 2001, tree damage on the lower (river side) of the treated road was evident. The pattern of damage was easily discerned; most severe damage occurred in mature western redcedar, Douglas-fir, grand fir and ponderosa pine that were closest to the road edge and most discoloration is high in the crowns of these trees. This pattern and the known toxicity of chloride (Cl^-) in plants suggested absorption of chloride ions by the trees as the cause of their demise.

Studies of phytotoxic effects of calcium chloride were funded by National Cooperative Highway Research Program; published in 1976. The studies, conducted by researchers at Virginia Polytechnic Institute and State University, investigated relative tolerance of 18 species of woody plants in three different physiographic regions to both sodium chloride and calcium chloride (Hanes and others 1976). In the controlled experiments, calcium chloride was applied at rates of 1,500, 3,000 or 6,000

United States Department of Agriculture | Forest Service | Northern Region | 200 East Broadway, P.O. Box 7669, Missoula, MT 59807

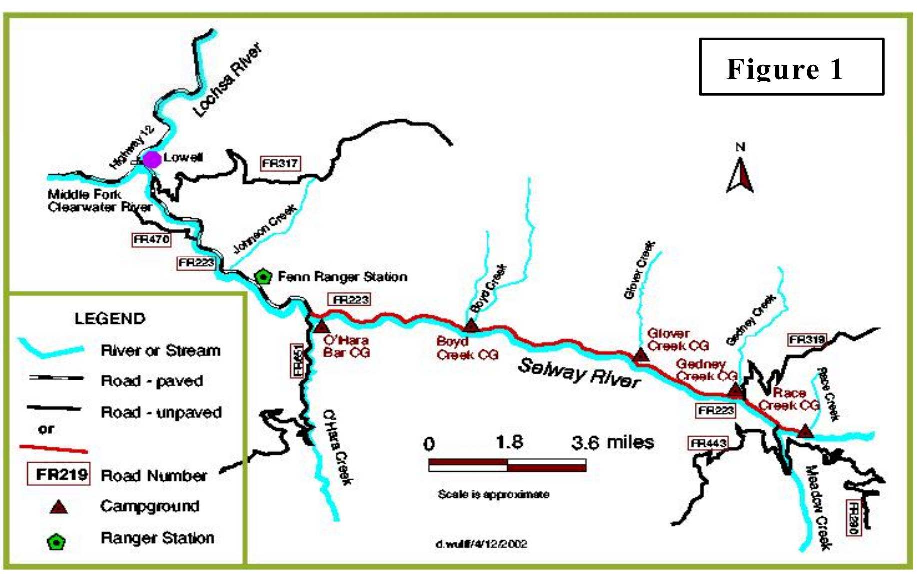
lbs/acre to soil near evergreen plants. Three of the evergreens (eastern white pine, Norway spruce and Canadian hemlock) were salt-sensitive, severely injured at the lowest application rate of 1,500 lbs/acre and did not survive the first summer after treatment. Salt-tolerant evergreens (creeping juniper, Pfitzer juniper and Adams needle) survived even the highest rates (6,000 lbs/acre) although they were damaged. By comparison, applications of calcium chloride flakes ranged from 19,000 to 31,000 lb./acre on Selway River Road. It is likely that the material used on the Selway River Road was the commercial dihydrate form (77% $CaCl_2$) rather than the more concentrated anhydrous form, although both are commercially available. If this is the case, actual $CaCl_2$ application rate was about 15,000 lb./acre (4 lb./yd^2) up to 25,700 lb/acre (6.9 lb./yd^2), with the rate of 18,600 lb./acre (5lb./yd^2) used on most of the treated road (Monlux and Calcaterra 2001).

EVALUATION METHODS

Survey and sampling for this evaluation was done without previous knowledge of patterns and concentrations of the chloride treatment test. I knew only that dust abatement treatment had been applied on some parts of the Selway River Road. The intent was to avoid prejudice in assigning tree damage ratings. A general condition survey was followed by installation of sample transects and, finally, foliar sample collection for chemical analysis.

GENERAL CONDITION SURVEY

The river-side stands of trees were evaluated for crown symptoms due to all causes along approximately 12.5 miles of road. Stands along the road were initially assigned ratings of none, low, moderate and severe according to frequency and severity of crown symptoms, starting at the end of the road near Race Creek campground and proceeding downstream to the bridge at O'Hara Bar (Figure 1).



The survey began approximately 12.5 miles upstream from the end of pavement, at the end of the Selway River road. Race Creek Campground and the "Raft Landing" signs are landmarks nearest the first trees included in the survey. These are approximately one half mile upstream from milepost 19. The general condition of the river-side stand of trees was noted. Where the condition changed, the odometer reading was noted. This general survey provided context for five intensively sampled ½-mile transects. The sample transects, in which each tree was tallied, began just downriver from the Gedney Creek Bridge.

SAMPLE TRANSECTS

The general condition survey was followed by tallying a 2½-mile sample of all trees within approximately 30 horizontal feet from the road edge on the river side (generally west) of the road. Initial sampling was completed on June 20 through 22, 2001. The sample consisted of five ½ mile transects. The first transect started at Gedney Creek, proceeding downriver, with additional ½ mile transects tallied beginning at miles 2, 4, 6, and 8.

Mileage was gauged using the car odometer in 1/10 mile increments. Trees were tallied sequentially starting with the southern-most trees (upriver) in each transect. Seedlings (trees less than .1 inch d.b.h.) were counted by species and chloride symptom condition class. Diameter at breast height (d.b.h) of all trees was measured or estimated by 2-inch diameter classes with the exception of small tree classes (<.1 inch, .1 to 1 inch, and 1-2 inches d.b.h.) Tree species were recorded and, according to species, certain common diseases or declines were rated for each tree. These included needlecasts and blights of ponderosa pine, Douglas-fir and grand fir and cedar decline for western redcedar. Severity of these disease or decline symptoms was rated as none, low, moderate or severe. Each tree was rated for relative severity of chloride damage symptoms.

Relative nearness of trees to the road was recorded by "zone". In zone 1, the base of the stem nearest the road was within 2 horizontal feet of the edge of the road. In zone 2, the nearest part of the stem was within 10 horizontal feet of the road, and in zone 3 the stem was approximately 10 to 30 feet from the road. Trees more than 30 feet from the road were not recorded.

All tallied trees in the transects were examined again on December 27 and 28, 2001, at which time changes in severity ratings and other notable damages were recorded.

SYMPTOMS THOUGHT TO BE ASSOCIATED WITH CHLORIDE DAMAGE

Chloride symptoms were distinct in western redcedar, by far the most abundant species in the sample. Foliage was discolored red, particularly at the tips of branchlets. Discoloration was most pronounced at tops of trees and ends of branches (Figure 2). It frequently was seen concentrated in the part of the crown adjacent to the road although the opposite case was also observed on occasion.

Chloride symptoms in Douglas-fir fir, grand fir and ponderosa pine were more difficult to distinguish in the June examination. Like cedar, foliage was most discolored at tops of trees. The most severely affected trees had shed all except the current growth (2001 flush).

The tips of needles were red whether on current or previous years' growth. Current growth in severely affected trees tended to be yellow with red tips. These trees appeared to have little chance of recovery. It was somewhat more difficult to distinguish between needlecasts and chloride damage in less severely affected trees.

By December, chloride symptoms were more pronounced in all species and very distinct from other types of damage such as needlecasts. In particular, in pines foliage killed by chloride damage was curled at the tips. New growth was short, both terminal and needle length were less than seen in unaffected trees.

In Douglas-fir, grand fir and western redcedar, the distal part of the needle was red and curled while the basal portion was yellow or pale green (Figure 3). Also in December, the pattern of damage in trees was more telling than it had been earlier in the season. Live trees often had completely dead tops with scattered limbs showing some green foliage lower in the crown. This pattern was particularly apparent in Douglas-fir.

CHLORIDE SYMPTOM SEVERITY RATING

Severity of chloride-related symptoms in all species was rated based on methods of Hanes and others (1976). They assigned numerical codes defined as follows: healthy (0), slight leaf scorching (1), moderate leaf scorching and slight defoliation (2), severe leaf scorching, moderate defoliation, minor limb dieback (3), and severe defoliation, extreme limb deterioration, tree death (4). To better fit conditions of this study, the rating system was further refined (Table 1) on the basis of percent of foliage discolored (leaf scorch). In June 2001 and still in October of that year, little leaf-fall had occurred in cedar trees although much of the foliage in all species of affected trees appeared dead. It was not until December that significant defoliation and branch dieback was seen. Also in December, many cedar trees had developed top death. This was then tallied as a specific symptom.

Table 1. Severity rating for presumed chloride damage foliage symptoms based on degree of leaf scorching (red or brown discoloration).

Code	Description
0	No evidence of chloride discoloration
1	Slight, less than 20% of foliage affected
2	Moderate, 20-75% of foliage/twigs affected
3	Severe, 75-90% of foliage/twigs affected
4	Extreme or dead, at least 90% of foliage/twigs affected

CHEMICAL ANALYSIS OF FOLIAR SAMPLES

On November 5, 2001, foliage samples were collected from 26 mature trees for chloride content analysis. In all cases except one, trees were alive and the foliage that was collected was at least partly green. Samples were taken from branches about 20 feet from the ground. Three each of Douglas-fir and ponderosa pine were selected from trees with apparent chloride symptoms in three different sample transects at varying distances from the road (see Table 6 in Results for details on sample tree locations). Because western redcedar was the most populous species in the stands, the sample was increased to 10 symptomatic trees of this species, again from a variety of transects and distances from the road. One dead ponderosa pine was also sampled. The tree was already dead when first examined in June 2001. It had

died shortly after bud break and the half-grown leaves were brown and curled. Since chloride is a highly leachable ion, I was interested to see if the chloride content would be comparable to that of live symptomatic pines.

Samples were collected from three control trees of each species for comparison. These trees were nonsymptomatic trees that were at least 100 feet from the road on the uphill side.

Fresh samples were sent to Dr. Ronald Etheridge at the Poultry Research Laboratory, University of Georgia. Dr. Etheridge dried and ground the samples and analyzed the percent of chloride and percent of moisture of each sample. From this I calculated the percent of chloride by dry weight, which allowed a direct comparison with results of the National Cooperative Highway Research study (Hanes et al 1976).

SUMMARY OF RESULTS

THE GENERAL CONDITION SURVEY

Of the roughly 12½ miles surveyed, nearly half (48.8%) were rated low for chloride symptom severity in June (Table 2). Most of the remainder was rated moderate (37.6%). Most mortality observed in June occurred in the portions of the stand rated severe.

Table 2. Chloride damage tallied in the general condition survey.

Chloride Symptom Severity	Miles	% of Survey
None	0.6	4.8
Low	6.1	48.8
Moderate	4.7	37.6
Severe	1.1	8.8

One third (34%) of the treated miles received an application of 6.8 to 6.9 lb/yd^2 of calcium chloride (25,300-25,700 lb/acre) as well as basalt aggregate (Table 3).

Table 3. Summary of chloride symptom severity from general survey by road treatment.

Road Treatment	Miles	% of Road	% None	% Low	% Mod.	% Severe
6.9 lb./yd^2 $CaCl_2$ (25,700 lb./acre) [5 lb./yd^2 $CaCl_2$ mixed, 1.9 lb./yd^2 $CaCl_2$ on surface. Basalt aggregate added.]	2.7	21	0	31	54	15
6.8 lb./yd^2 $CaCl_2$ (25,300 lb./acre) [6.8 lb./yd^2 $CaCl_2$ mixed. Basalt aggregate added.]	1.6	12	0	31	69	0
5.0 lb./yd^2 $CaCl_2$ (18,600 lb./acre) [5 lb./yd^2 $CaCl_2$ mixed. Basalt aggregate added.]	7.5	58	1	55	36	8
5.0 lb./yd^2 $CaCl_2$ (24,000 lb./acre) [5 lb./yd^2 $CaCl_2$ mixed. No basalt added.]	0.2	2	0	0	100	0
4.0 lb./yd^2 $CaCl_2$ (15,000 lb./acre) [4 lb./yd^2 $CaCl_2$ mixed. Basalt aggregate added.]	0.3	2	0	0	100	0
No $CaCl_2$ added [Basalt aggregate added.]	0.3	2	100	0	0	0
No $CaCl_2$ added [No basalt added.]	0.3	2	100	0	0	0

Another 60% of treated miles received 5 lb./yd^2 and basalt aggregate.

Unfortunately, there were few trees along the section of road where no chloride symptoms were observed. The untreated section, and that receiving only basalt aggregate (no calcium chloride), happened to correspond to a road segment that had very few trees on the river side.

Proportions of the roadside stand rated none, low, moderate and severe for general symptoms of chloride damage corresponded fairly well with amounts of calcium chloride applied. Chloride symptoms were rated moderate to severe along 70% of the 4.3 miles of these two treatments (Table 3). There were not an adequate number of trees along road lengths that did not have basalt aggregate added to test possible effects of this part of the treatment.

Details of the general condition survey are provided in Appendix A at the end of this report. Car odometer readings correspond only roughly with the mileage posts. Locations of posts are noted in Appendix A. In the case of milepost 15, there are two posts to indicate milepost 15; they are placed approximately 50 feet apart. It was quite brushy along the road and I'd guess someone thought the milepost was gone so replaced it with another but didn't get it in the same spot.

THE SAMPLE TRANSECTS

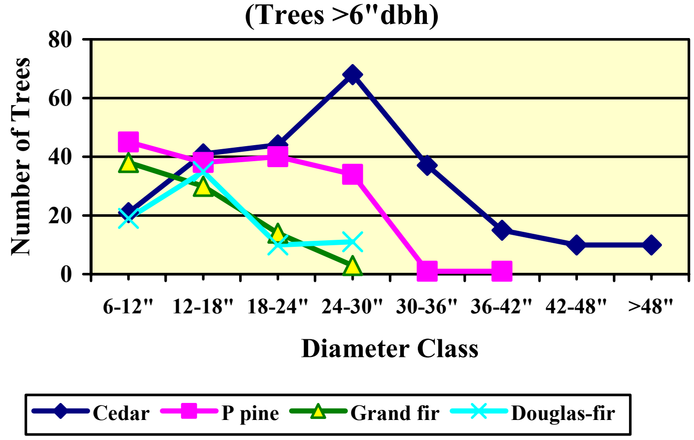
A total of 1,189 trees were tallied in the 2½ mile by 30 ft. sample. The species distribution is shown in Table 4.

Table 4. Species composition of sample.

Species	<6" d.b.h	>6" d.b.h	All sizes
Western redcedar	28	249	277
Douglas-fir	162	80	242
Englemann spruce	2	1	2
Grand fir	290	79	369
Ponderosa pine	121	164	285
Pacific yew	10	2	12
Western white pine	1		2

Western redcedar was the most numerous of the trees that were larger than saplings (>6 inches d.b.h), and it was the only species represented in the largest diameter classes (Figure 4). It was by far the most important species in the roadside stand. Ponderosa pine was the second most important species in the stand. Most regeneration (trees under 6 inches d.b.h) was grand fir and Douglas-fir.

Figure 4. Species Composition by Size (Trees >6"dbh)



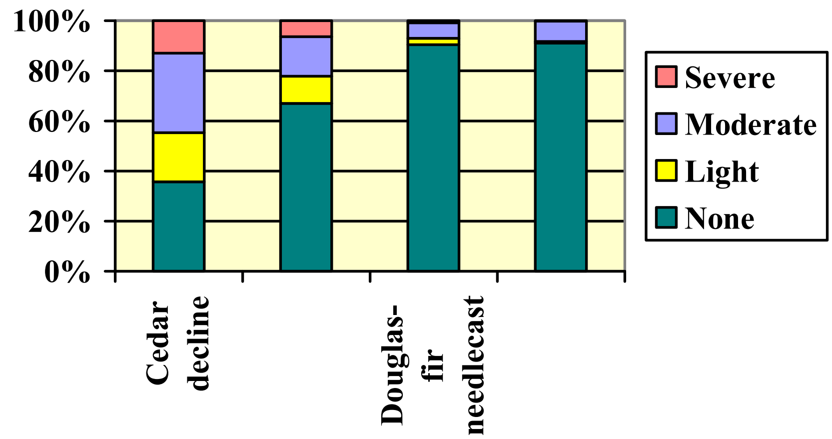
CEDAR DECLINE AND NEEDLE DISEASES IN THE TRANSECTS

Cedar decline is a phenomenon of unknown cause that is common in western redcedar. It is generally believed to be associated with advanced age but is sometimes seen in younger trees as well. It appears as a general decline in crown vigor. Dead branches appear at random throughout the crown, top dieback is common. Crowns are thin, particularly near the tops of trees. Advance decay of roots is often seen in declining cedars.

Foliage discoloration is usually limited to slight chlorosis in severely afflicted trees so there was little concern that discoloration seen in chloride-affected trees could be confused with cedar decline symptoms. However, gradual, chronic defoliation is a primary symptom of cedar decline. Therefore, for the purpose of differentiating between cedar decline symptoms and chloride damage symptoms, it was important to examine trees before significant loss of foliage due to chloride damage had occurred. Based on scarcity of shed branchlets under thin-crowned trees, it was apparent that chloride damage had not caused much branchlet shedding at the time transects were established (June 20-22, 2001.)

Sixty four percent of cedar trees exhibited some degree of decline (Figure 5). Of these, 20% were severely afflicted. In general, severe symptoms include at least 75% defoliation and some amount of top dieback. Even so, death is usually decades away.

Figure 5. Frequency of non-chloride causes of foliar symptoms.



Needle diseases

Needle diseases of ponderosa pine (*Dothistroma pini*), Douglas-fir (*Rhabdocline* spp. and *Phaeocryptopus gaumannii*) and grand fir (mostly *Epipolaeum abietis*) are common, particularly along the river. They appear, in many ways, similar to chloride damage except they do not discolor current year's growth, never cause curling of killed needles, and tend to be more to the lower portions of trees.

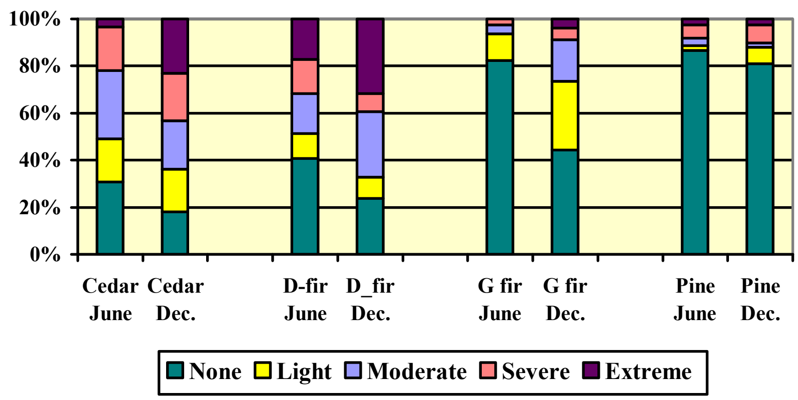
Trees showing some chloride damage that occurred last season would appear very similar to those with needlecast infections of last season's needles. That is, the 1-year old (and older) needles are red or red-tipped in spring and early summer and may be cast by late fall. However, discoloration of current season's growth is not attributable to needle disease in these tree species.

CHLORIDE DAMAGE SEVERITY IN THE TRANSECTS

Relative Chloride Tolerance of Tree Species

Western redcedar and Douglas-fir were proportionally more damaged than other species (Figure 6). In June, about 70% of cedar trees along treated segments of the road had obvious chloride symptoms; by December this number

Figure 6. Chloride damage by species (>6"dbh) in June and December, 2001.



had increased to 82%. The proportion of Douglas-fir affected (76% in December) was slightly less than that of cedar, but the proportion killed was higher (nearly a third.) Grand fir appeared to be fairly tolerant to chloride in June but had shown dramatic increases in symptoms by December. Ponderosa pine exhibited, by far, the greatest resistance to damage by calcium chloride.

Cedar, Douglas-fir and grand fir increased in relative numbers of severe and extremely damaged trees. At the time of the December examination, the death toll among the 576 large trees (>6 inches d.b.h) in sample transects was increased to nearly 80% by December. Nearly half the trees in the sampled zone farthest from the road (10-30 feet), had symptoms of chloride damage by December.

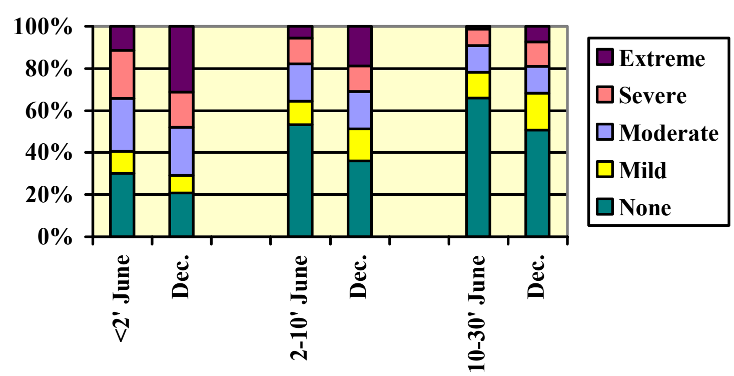
50 (9%) with an additional 53 (10%) that appeared to be nearly dead. Of the dead, 27 were cedar, 18 Douglas-fir, 4 ponderosa pine and 1 grand fir. Dead cedar averaged 24 inches d.b.h; Douglas-fir averaged 15 inches d.b.h, and ponderosa pine, 19 inches d.b.h. Most of the nearly dead (41 of 53) were cedar.

Most damage occurred in trees that were at least 6 inches d.b.h. Probably owing to the limited root systems of smaller trees, only those within a couple of feet of the road edge exhibited chloride damage symptoms. Small trees (<6 inches d.b.h.) that were damaged, typically did not survive until the December examination.

PROXIMITY TO TREATED ROAD

The proximity of trees to the roadside had quite a bit of bearing on severity of symptoms (Figure 7). Just over 70% of trees (>6 inches d.b.h) that were within 2 feet of the road had symptoms of chloride damage in June. This increased to

Figure 7. Severity of chloride symptoms compared to proximity of trees (>6"dbh) to road edge.

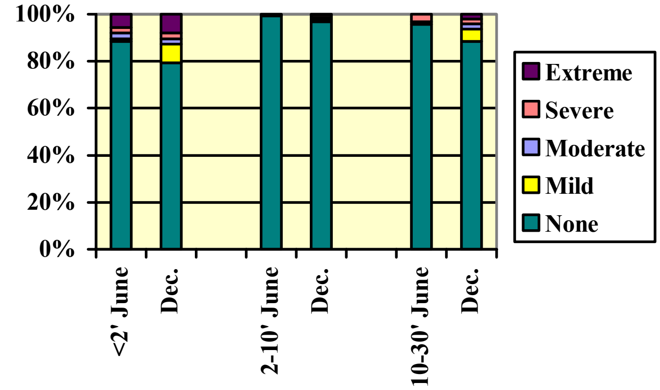


nearly 80% by December. Nearly half the trees in the sampled zone farthest from the road (10-30 feet), had symptoms of chloride damage by December. Mortality is another matter, however, and it appears that relatively little mortality is likely to take place in trees more than 10 feet from the road. As of December 2001, 28% of trees nearest the road (Zone 1) had died. In Zone 2, 12% were dead, and in Zone 3, only 3% had died.

In June, 11% of these trees had obvious signs of chloride damage. f these, fully half were dead. Damaged seedlings and saplings had increased to 21% in Zone 1 by December, with nearly 40% of these dead. The sample contained 384 seedlings and saplings in zone 2 (2-10 feet from road). Of these, a total of 12 were damaged and only 1 had died by December. Zone 3 (10-30 feet from road) had 95 trees tallied, 11 damaged, and 2 killed.

Even in the zone closest to the treated road, few seedlings and saplings exhibited chloride damage symptoms (Figure 8). The sample included 87 seedlings and saplings (trees <6 inches d.b.h.) within 2 feet of the road (zone 1.)

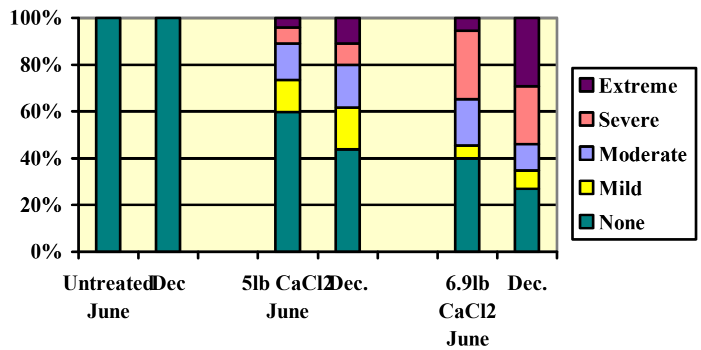
Figure 8. Severity of symptoms compared to proximity of seedlings and saplings to road edge.



EFFECT OF CALCIUM CHLORIDE APPLICATION RATE

The severity of foliage discoloration and loss was closely associated with the relative amount of calcium chloride that had been applied to the road (Figure 9). Only the 5lb/yd^2 and 6.9 lb/yd^2 treatments had a sufficient number of trees that were at least 6inches d.b.h to provide an adequate sample. Untreated sections (designated Sections 3 and 5) included only 21 trees (>6 inches d.b.h) in the zone up to 30 feet. from the road edge. None of these trees had symptoms of chloride damage. The 4 lb/yd^2 $CaCl_2$ treatment (Section 4) had only 14 trees. All three of these treatments fell on road segments that have very few trees on the river side.

Figure 9. Chloride symptom severity by calcium chloride application rate
(Trees >6"dbh.)



Only one treatment, 5lb/yd^2, was represented in multiple sample transects. The three ½-mile transects which represented this treatment varied quite a bit in percent of trees showing obvious symptoms of chloride damage in June (from 28 to 56%). However, by December rates were much more similar (from 48 to 58%.) The percent of trees dead or dying (severity class 4) in December ranged from 6% to 13% in this treatment.

The number of trees per sample transect varied from a low of 58 large trees (>6 inches d.b.h) in the 6.0 to 6.5 transect, to a high of 163 in the 4.0-4.5 transect.

The most highly damaged transect (8.0-8.5) was had the highest $CaCl_2$ application rate, 6.9lb/yd^2 (Table 5). In June, only 40% of trees in this transect were without obvious symptoms and by December, 29% were in the "extreme" damage class, 66% of which had been killed.

Table 5. Distribution of chloride symptom severity classes in trees >6 inches d.b.h, by ½-mile sample transects.

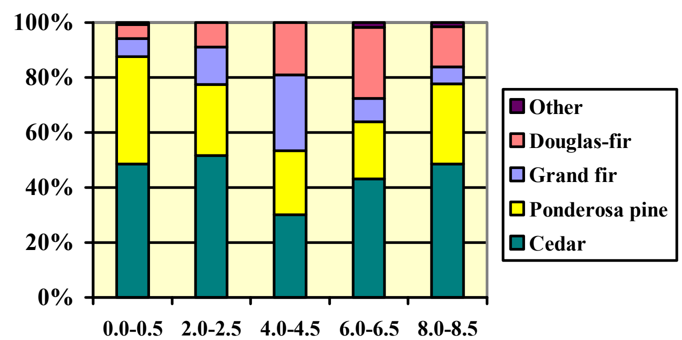
Transect	Road treatment (Segment)[1]	Chloride symptom severity. % of trees in June and December, 2001										Total Trees >6 " d.b.h
		0		1		2		3		4		
		Jun	Dec	Jun	Dec	Jun	Dec	Jun	Dec	Jun	Dec	
0 – 0.5	5lb (7)	44	42	16	15	29	21	8	10	3	13	136
2.0 – 2.5	5lb (7)	65	52	19	22	7	10	7	6	2	10	89
4.0 – 4.5	5lb (7)	72	44	10	18	10	20	6	11	2	6	163
6.0 - 6.5	None (5)	100	100	0	0	0	0	0	0	0	0	6
6.0 – 6.5	4lb (4)	64	64	7	7	14	0	7	7	7	21	14
6.0 – 6.5	None (3)	100	100	0	0	0	0	0	0	0	0	15
6.0 – 6.5	5lb (2A)	48	22	4	13	9	22	9	9	30	35	23
8.0 – 8.5	6.9lb (1)	40	27	5	8	20	12	29	25	5	29	130
Weighted Average		57	43	11	15	16	16	12	12	4	15	576

Transect 4.0-4.5 changed most dramatically from June to December, having 72% without chloride symptoms in June and only 44% remaining symptom free in December. This transect had been treated using the "standard" application of 5lb/yd^2 $CaCl_2$ with aggregate added.

Western redcedar, ponderosa pine, grand fir and Douglas-fir were present in all transects (Figure 10). Cedar was the most abundant species in the >6 inches d.b.h. class in all transects.

Figure 10. Species composition of transects

(Trees >6"dbh)



COMBINED EFFECTS OF $CaCl_2$ APPLICATION RATE AND PROXIMITY TO ROAD

The proximity of the road and amount of $CaCl_2$ used were the most significant factors in determining severity of symptoms in trees that were at least 6 inches d.b.h. Controlling for distance from treated road, linear regression of mean symptom severity on $CaCl_2$ application rate produced an R^2 of .99 (Figure 11).

An analysis of variance indicated that application rate alone accounted for 51% of variance, regardless of proximity to the road (within 30 feet) or tree species. Power regression of the midpoint of distance classes from the road treated with 5 lb/yd^2 of $CaCl_2$ (the largest sample population) produced R^2 = .99 (Figure 12).

Figure 11. Regression of symptom severity in Zone 1 on $CaCl_2$ application rate

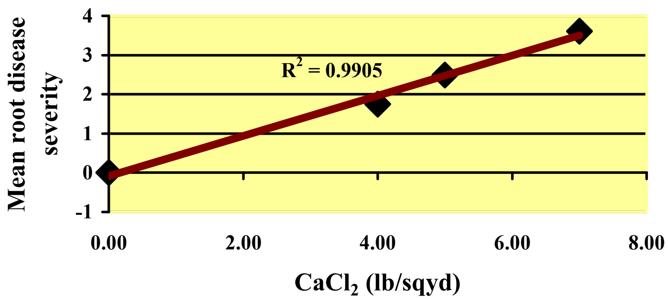
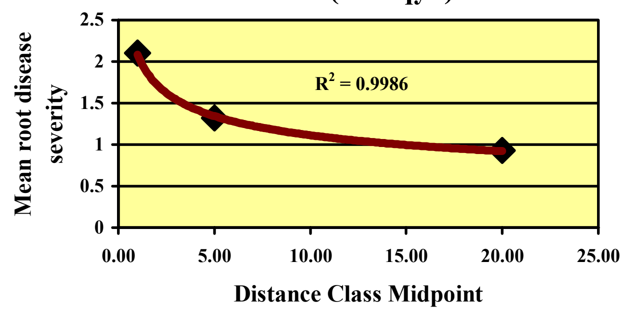


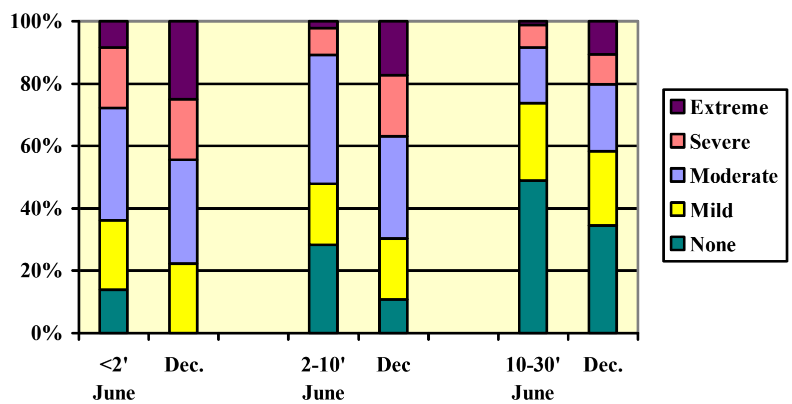
Figure 12. Power regression of symptom severity on proximity to treated road (5lb/sqyd).



Probably of greatest interest in these stands along the Selway road are the larger cedar trees that give the river corridor its unique scenic quality. Figures 13 and 14 illustrate trends in condition of most of the cedar. Two treatments, 5lb/yd^2 and 6.9 lb/yd^2 account for 92% of cedar trees along the Selway River road. By December 2001, all of the sample cedar nearest the road in the segment having 6.9lb/yd^2 $CaCl_2$ added had severe or extreme crown symptoms. Most of these trees appear likely to be dead within months. According to Monlux and others (2001), this treatment was applied to 2.7 miles of road.

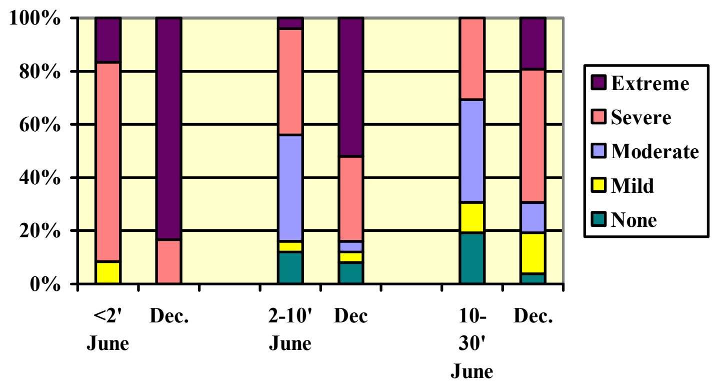
Figure 13. 5lb/sqyd $CaCl_2$; Severity of symptoms of >6"dbh western redcedar.

Shown by distance from road and month of survey (2001).



About a third of the sample cedar along the 7.6 miles of road to which 5 lb/yd^2 was applied had severe to extreme symptoms in December 2001. Although many or most of these are expected to die, recovery is likely for many of the remaining 70% of cedar with less severe symptoms (damage ratings moderate or less.)

Figure 14. 6.9 lb/sqyd $CaCl_2$; Severity of symptoms of >6"dbh western redcedar.
Shown by distance from road and month of survey (2001.)



Variability of symptoms of trees, even in the zone closest to the road, is probably mostly a result of individual tree root morphology. Mature western redcedar and Douglas-fir (Eis 1974) can be expected to have an average root radius in excess of 10 m (32.8 feet) and roots of dominant ponderosa pine may exceed 25m (82 feet) at 60 years of age (Stone and Kalisz 1991). Root morphology is known to vary greatly among individual trees. Physical barriers such as boulders, hardpans and water table, produce asymmetry in root systems. For this reason, individual trees that are far from the road but have roots extending in the direction of the road could easily absorb more chloride from the vicinity of the road than trees which are adjacent to the road but have roots extending mostly away from it.

Although the taproot and sinkers generally extend downward until reaching a barrier such as hardpan or a fluctuating water table, absorbing roots (fine roots) occur mostly in the upper 20 cm (roughly 8 inches) of soil. Therefore, it is logical to assume that most of the chloride absorbed by trees was located in the upper few inches of road or adjacent soil.

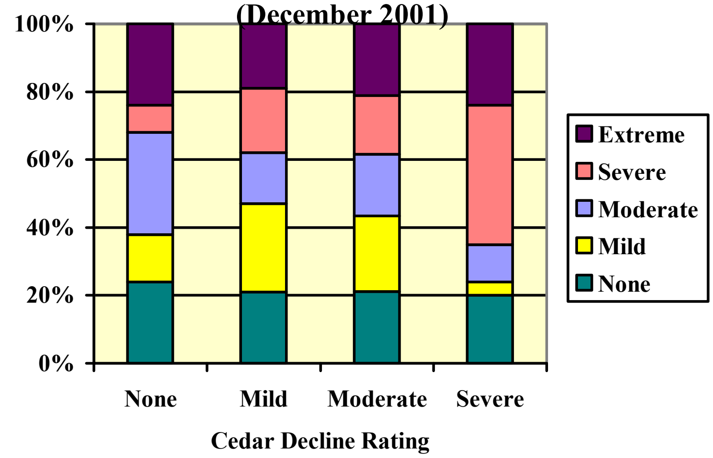
CEDAR DECLINE AND CHLORIDE DAMAGE

There was not a statistical relationship between the severity of cedar decline (prior to June 2001) and the severity of effect of chloride in December 2001 (Figure 15.) Trees with severe pre-existing decline symptoms had little foliage remaining even in June 2001 and often had dead (spike) tops. These are typical symptoms of advanced cedar decline. Of the 46 cedars rated severe for cedar decline in June, 30 had severe or extreme chloride damage in December. It appeared that although the trees with pre-existing decline were not more likely to have chloride symptoms, they were more likely to be severely damaged if affected at all.

Cedar decline is a very slow process of deterioration of mature cedar. It gives old cedar the characteristic spike-top appearance seen throughout the Clearwater drainage. The level of decline in cedar along the Selway Road is typical of that elsewhere in cedar type.

Mortality from chloride damage appears to be evenly distributed among the cedar decline

Figure 15. Chloride damage in cedar compared to previously-existing decine symptoms.
(December 2001)



classes. This further indicates that the two factors most responsible for variation in damage are the adjacency of the tree to treated road, and the individual root morphology that brings the fine roots in contact with concentrations of chloride.

CHLORIDE CONTENT OF FOLIAGE

Foliage samples collected from live trees along treated sections of the road all yielded higher concentrations of chloride than did samples from trees that were not near the treated road (Table 6).

Table 6. Samples analyzed for total chloride content on 5 November 2001, approximately 17 months after road application of $CaCl_2$. Chloride content reported as percent of sample dry weight.

Sample	Species	Tree	DBH	Zone	Sev 06[1]	Sev 12	Cond.[2]	$CaCl_2$	Rd Seg	% Cl
1	DF	63	14	2	3	4	D	5	7	1.223
2	DF	625	20	2	4	4	D	5	2A	0.675
3	DF	458	16.2	2	4	4	UT	5	7	1.108
4[3]	PP	834	22	2	4	4	D	6.5	1	0.376
5	PP	430	20	3	3	3		5	7	0.584
6	PP	622	16	1	2	3		5	2A	0.909
7	PP	69	28	3	2	3	U	5	7	0.887
8	C	652	16	3	3	4	D	5	2A	0.233
9	C	129	22	1	4	4	UT	5	7	0.311
10	C	81	28	2	4	4	UT	5	7	0.870
11	C	267	18	3	4	4	D	5	7	0.357
12	C	14	32	2	3	3	UT	5	7	1.035
13	C	144	33.5	1	3	4	UT	5	7	1.154
14	C	538	28	1	2	3	T	5	7	0.435
15	C	829	38	1	4	4	D	6.5	1	0.922
16	C	832	16	2	4	4	D	6.5	1	1.054
17	C	737	24	3	3	4	D	6.5	1	0.905
18	DF	C1	14.8		0	0		0		0.016
19	DF	C2	15.3		0	0		0		0.096
20	DF	C3	21.2		0	0		0		0.022
21	PP	C4	24.6		0	0		0		0.018
22	PP	C5	27.9		0	0		0		0.023
23	PP	C6	18.8		0	0		0		0.022
24	C	C7	28.5		0	0		0		0.062
25	C	C8	19.7		0	0		0		0.117
26	C	C9	32.3		0	0		0		0.147

[1]Sev 06 = Chloride symptom severity in June 2001, Sev 12 = severity in December 2001.

[2]Codes for condition in December 2001; D = dead, U = unlikely to survive (appears nearly dead), T = topkill, UT = topkilled and unlikely to survive.

[3]This tree was the only sampled tree that was dead when first examined in June 2001. It had died shortly after bud break

In the case of Douglas-fir, the treated sample averaged 50 times more chloride than the control. Treated ponderosa pine averaged just over 30 times greater chloride than controls. Western redcedar showed the least difference, with nearly seven times greater chloride than the control (Table 7).

Only one dead tree was sampled. Ponderosa pine #834 was dead when transects were established in June 2001. The 16-inch diameter tree had died shortly after bud break as indicated by the wilted, incompletely expanded shoots. Foliage from the 2000 growing season, which was the only foliage remaining on the tree, was curled and red-brown in June 2001. When the sample for chloride analysis was collected in November of 2001, foliage had turned gray but remained attached to branches. I wanted to see if the chloride content was similar to other symptomatic trees even though the tree had been dead for several months. Although the chloride content was still 18 times greater than the control average for ponderosa pine, it was somewhat lower than that of live symptomatic pines. It is evident that chloride poisoning was the cause of death and if chloride was leaching from deteriorating foliage, it was happening slowly because considerable chloride was still present.

Table 7. Summary of 26 samples analyzed for foliar chloride content on November 5, 2001.

	Species	Control	Treated	Factor (treated/control)
% Cl_2 (Average)	Cedar	0.109	0.728	6.7
	Douglas-fir	0.019	1.002	52.2
	Ponderosa pine	0.021	0.689	33.7
DBH (Average)	Cedar	26.8	25.6	
	Douglas-fir	17.1	16.7	
	Ponderosa pine	17.8	21.5	
Severity June 2001	Cedar		3.4	
Severity Dec. 2001	Cedar		3.8	
Severity June 2001	Douglas-fir		3.6	
Severity Dec. 2001	Douglas-fir		4.0	
Severity June 2001	Ponderosa pine		2.8	
Severity Dec. 2001	Ponderosa pine		3.3	

According to Singer and others (1982) “absorbed” chloride is needed only in small amounts by plants but it also may be very toxic at low concentrations. Studies have correlated high levels of chloride (Cl-) in foliage and twigs with foliage damage where $CaCl_2$ was used on adjacent roads (NRCC 1977). A technical bulletin on chlorides issued by Environment Canada, Environment Protection Service (1984) lists the chloride ion threshold limit for chronic plant toxicity in water as 100 ppm. T his figure is likely to vary greatly by plant species because salt tolerance is known to vary widely.

Hanes and others (1976) reported that the three conifer species that were most injured by salts (eastern white pine, Norway spruce and Canadian hemlock) absorbed 7 to 15 times more chloride than untreated plants. This was sufficient to kill all of the treated plants. Their percent dry weight chloride content for untreated trees of these conifer species was comparable (0.04) to those found in the Selway control samples for western redcedar (0.11), Douglas-fir (0.02) and ponderosa pine (0.02). In the Selway samples, on average, treated trees had absorbed from 7 to 50 times as much chloride compared to untreated samples. Trees near the Selway River road having higher concentrations of chloride in foliage is consistent with higher application rates of calcium chloride on the Selway Road (from 2.5 to 4 times higher than the highest rates tested by Hanes and others.)

Vischer (2001) reported that in two of three sites he sampled in June 2001 on the Selway Road, little of the chloride that had been applied a year earlier remained in the upper 4 inches of the road. He noted that heavy rainfall in September through November of 2000 may have caused removal of much of the chloride through runoff. Damaged trees are mostly downslope from the road. Perhaps much of the transported chloride was deposited in the soil downslope of the road where it would be even more available to fine roots of trees. With sufficient runoff, some chloride may have moved into the adjacent river, and was thus transported away from the site. Since a considerable amount of chloride was found in tree foliage, this may account for much of the “missing” chloride as well.

Chloride ions are readily soluble in water and easily transported by moving water. Hanes and others (1976) reported rapid leaching of ions from calcium chloride deicer through the soil profile. Under natural rainfall conditions for Virginia, 2 years after application of 6,000 lb/acre, chloride contents of soils were no higher than that of nontreated sites.

CONCLUSIONS

- Severity of crown symptoms is related to amount of $CaCl_2$ applied to the road. Higher application rates result in greater damage and greater distances from the road.
- Severity of crown symptoms is related to proximity of trees to treated road sections.
- Absorption of chloride by roots, and translocation to and accumulation in the upper crown, is the most probable mechanism for observed tree damage. Deposition of chloride in dust or salt spray on foliage is unlikely mechanisms.
- Douglas-fir exhibited the least tolerance to chloride, followed by western redcedar and grand fir. Ponderosa pine exhibited the greatest tolerance.
- Conditions of trees have continued to worsen since June 2001, indicating that we probably will see additional mortality in the coming (2002) growing season.

LITERATURE CITED

Eis, S. 1974. Root system morphology of western hemlock, western red cedar, and Douglas-fir. Can. J. For. Res. 4: 28-38.

Environment Canada 1984. Calcium Chloride. Enviro Technical Information for Problem Spills. Environment Canada, Environmental Protection Service, Ottowa, Ontario. May 1984. 76 p.

Hanes, R. E., L. W. Zelazny, K. G. Verghese, R. P. Bosshart, E. W. Carson, Jr., R. E. Blaser, and D. D. Wolf 1976. Effects of deicing salts on plant biota and soil. Experimental phase. Virginia Polytechnic Institute and State University, Blacksberg, VA; Transportation Research Board, National Research Council, Washington, D. C., National Cooperative Highway Research Program Report 170. 88 p.

Monlux, S. and Jim Calcaterra 2001. Native road surface stabilization with calcium chloride. Selway River road, Nezperce National Forest. February 2001 Interim Report. USDA Forest Service, Northern Region. Unpublished report. 7 p.

Singer, R.D., Jeffrey B. Stevens, Janine R. Gleason, David Al Baker, Thomas M. Baker and Alan V. McEmber 1982. An environmental evaluation of dust suppressants: Calcium chloride and ligninsulfonates. US Dept. of Interior, Bureau of Mines; University of Minnesota, School of Public Health. Minneapolis MN. 33 p.

Stone, E. L. and P. J. Kalisz 1991. On the maximum extent of tree roots. For. Ecol. Manage. 46: 59-102.

Vischer, William 2001. Preliminary report of chloride concentration levels and movement within the soil for Region 1 road projects treated with chloride dust abatement/stabilization materials. R1 Materials Engineer, USDA Forest Service, Northern Region, Unpublished report. 4 p.

Appendix A. General condition survey.

Odometer reading	Nearest milepost	Overall rating	Notes
	19.0-19.5	Low	End of road Race Creek campground. C mild to none, 2 dead DF, 1 nearly dead PP.
	18.5-19.0	Moderate	PP with curled (wilted) terminals and dead distal ½ to 1/3 of needles.
	17.9-18.5	Moderate	Moderate to severe near road.
	17.6-17.9	Moderate	Upriver from Gedney Creek bridge. Most are PP, moderate; 3 dead DF, 1 dead C.
0-0.5	**17**	**Low**	**Average June severities all about 1 (Low), Average December severities 1-2 (Low to Mod.)**
0.5-0.6		Low	Mild to severe C. 2 large GF very severe.
0.6-0.75		Low	Mild to severe on C.
0.75-1.0		Moderate	Moderate to severe on cedar, Severe on some DF, GF, PP
1.0-1.25		Moderate	DF with current growth wilting/turning red.
1.25-1.4		N/A	No trees in this stretch
1.4-1.5		Moderate	DF w/ severe symptoms (Roll 2, photo 15)
1.5-1.6		Low	Not much discoloration in any spp.
1.6-1.7		Severe	Group of C are likely to die
1.7-1.9		Low	Few trees, fewer symptoms
1.9-2.0		Moderate	Moderate to severe, especially in C
2.0-2.2		**Low**	**Average June severities both 1 (Low), Average December severities 1.3-1.7 (Low to Mod.)**
2.2-2.4		**Very low**	**Ave. June severities <1 (very low), Ave. December severities 0.5-1 (very low to low)**
2.4-2.5	**15**	**None**	**Few trees, June and December severities both 0.**
2.6-2.7		Moderate	Moderate to severe.
2.7-2.9		Low	Trees present but have few symptoms.
2.9-3.7		Low	Few scattered trees show moderate to severe symptoms.
3.7-4.0		Moderate	Moderate to severe in most of the C.
4.0-4.1		**Low**	**Ave. June and December severities about 1 (low).**
4.1-4.2		**Low**	**Ave. June severity low, December moderate.**
4.2-4.5	**13**	**Low**	**Ave. severities very low in June to low in December.**
4.5-4.7		Low	Few symptoms
4.7-5.3		Moderate	Mild to severe, most C are affected
5.3-5.4		Low	Mild symptoms
5.4-5.5		Moderate	Moderate to severe symptoms.
5.5-6.0		Low	Very mild
6.0-6.1		**Low**	**Ave. June and December severities low.**
6.1-6.2		**Low**	**Ave. June severity low, December high moderate.**

Appendix A. General condition survey, continued.

Odometer reading	**Nearest milepost**	**Overall rating**	**Notes**
6.2-6.3		**None**	**Few trees. June and December severities almost 0.**
6.3-6.4	**11**	**None**	**Few trees. June and December severities 0.**
6.4-6.5		**Moderate**	**Ave. June severity moderate, December high mod.**
6.5-6.6		Severe	Severe in all species
6.6-6.8		Low	Mild to none- Boyd Creek campground
6.8-7.2		Low	Mild to none
Odometer reading	**Nearest milepost**	**Overall rating**	**Notes**
7.2-7.3		Low	Mild to moderate
7.3-7.8		Severe	Moderate to severe. Many dying at 7.4-7.5.
7.8-8.0		Low	Mild to none
8.0-8.1		**Low**	**Ave. June severity 1(low), December 2 (moderate.)**
8.1-8.2		**Moderate**	**Ave. June severity 1.6, December 2. 1.**
8.2-8.3		**Low**	**Ave. June severity 1.2, December 1.7.**
8.3-8.5	**9**	**Moderate**	**Ave. June severities 2, December 2.5.**
8.5-8.9		Severe	Severe to moderate mostly, some mild.
8.9-9.1		Low	Mild to none
9.1-9.2		Moderate	Moderate to severe overall
9.2-9.6		Low	None or mild
9.6-10.6		Moderate	Few trees. Clump of C at 9.8 with severe symptoms.